CMAQ V5.0 Upgrade for ozone and Particulate Matter Predictions

http://www.emc.ncep.noaa.gov/mmb/aq

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May 31, 2017

CMAQ weaknesses Identified

- Overprediction of ozone in Eastern U.S. in Summer
  - Especially along coastal areas (NYC, DC, Great Lakes)

    →Update National Emission Inventory point sources to 2011 (project to present)

    → *Adjust NOx emissions based on OMI satellite trends (deferred)*

    → *Evaluate Impact of NAM-X and reduced SW radiation under clouds*

    → *Update CMAQ gas and aerosol chemistry/biogenic emissions to EPA V5.0.2*

- Underprediction of particulate matter (PM) in Summer and near wild-fires

  → *Update 10 year old USFS BlueSky smoke emission system*

  → *Introduce 24 h pre-analysis cycle to correct fire time mismatch with CMAQ initial time*

- Underprediction of Ozone and PM during strong fire smoke/dust intrusions into CMAQ domain

  → *Test NGAC full aerosol predictions for CMAQ lateral boundaries*

- Overprediction of PM during winter-time stagnation episodes (cold, stable)

  → *update emissions/chemistry as in bullet 1*

  → *Test updates to bias correction*

Evaluations Performed

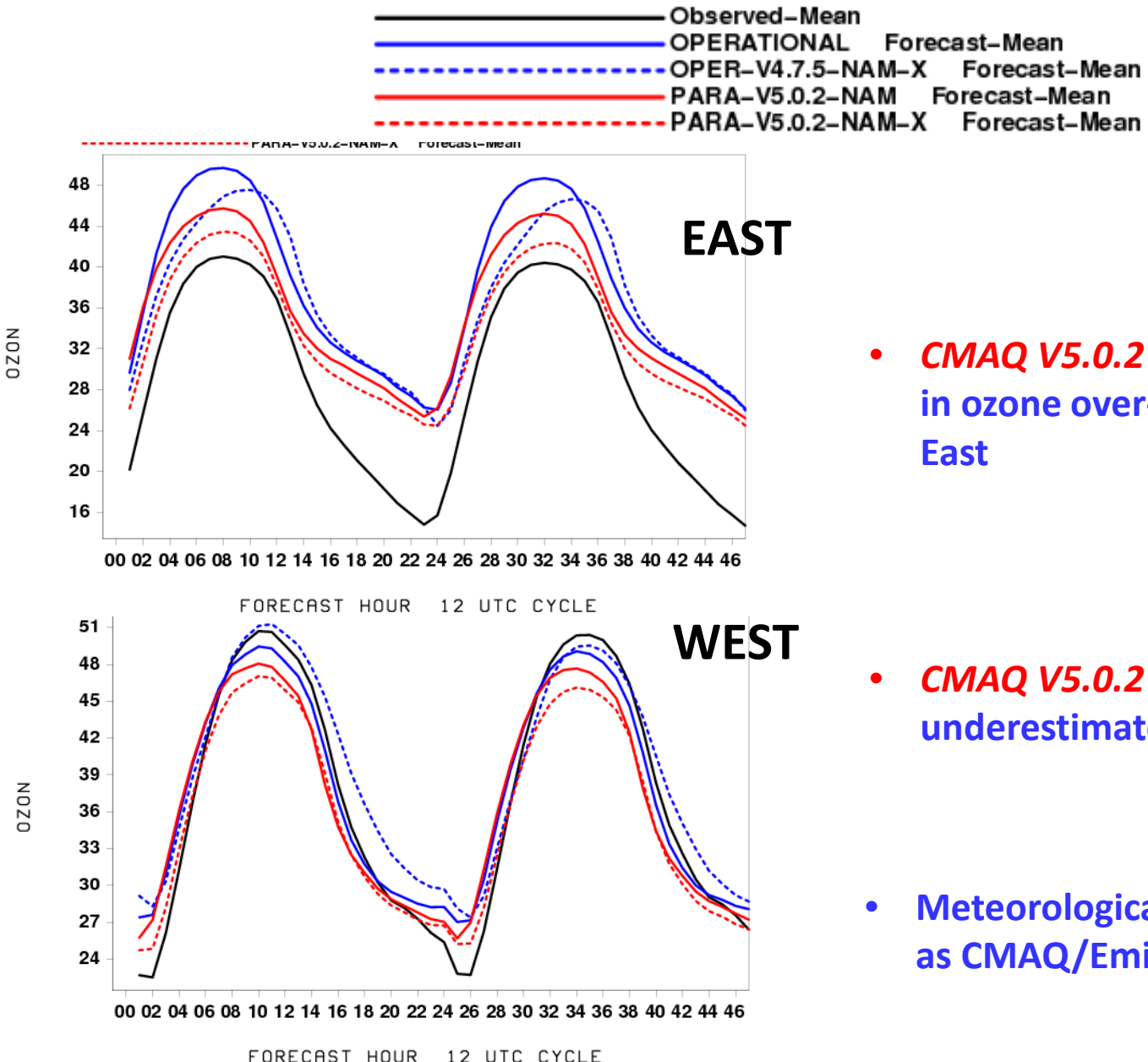
Ozone and PM

- ARL Preliminary: Aug. 2015/Feb. 2016
- EMC Real-Time: July 2016→March 2017
- NCO Real-Time: April 2017→Present
- EMC NAM-X Retrospectives : July 2016
- EMC/ARL NOx emissions adjustments : Aug-Sept. 2016 retros

- NWS/STI & AQ Focus Group: Aug. Retros + NRT runs
  - EMC maintains NRT comparison graphics and verification web sites
  - EMC provides daily text predictions at monitor sites to following state forecasters :
    - AL, AZ, CA, CT, DE,GA, IA, MD, ME, NY, OH, PA,TN,VA

July 2016 NRT CMAQ Prod vs V5.0.2

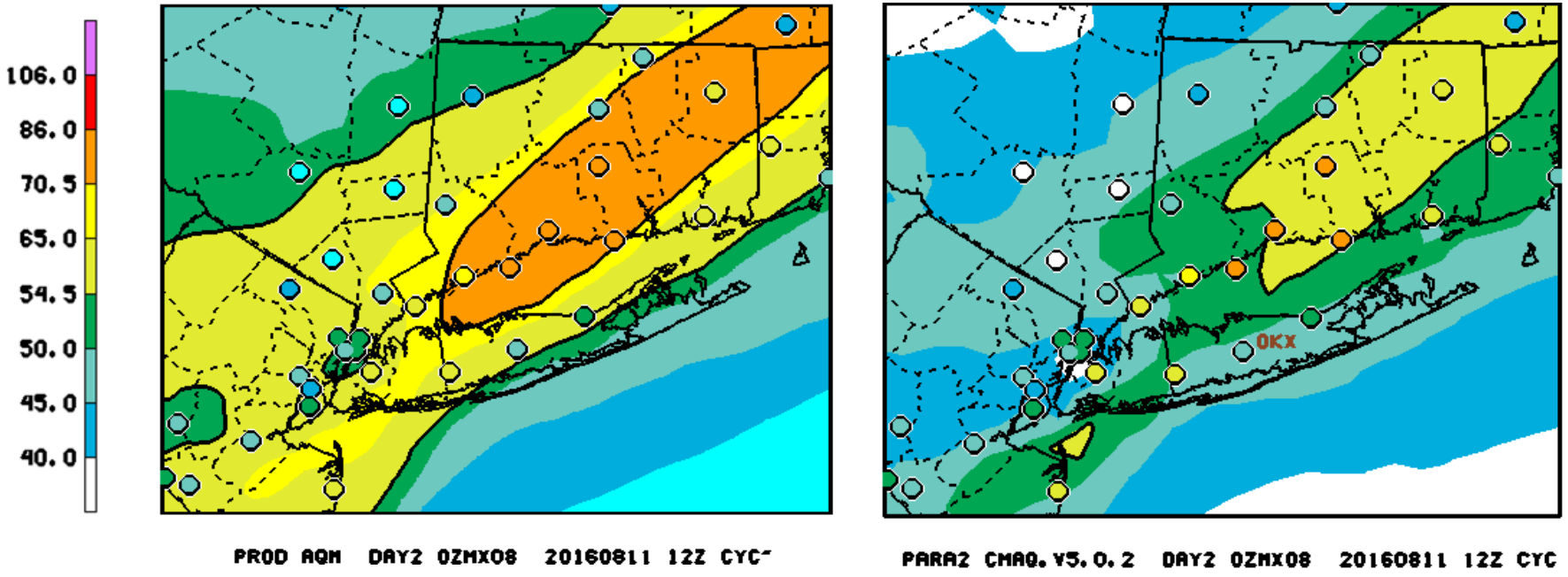
1 h avg Diurnal Ozone



- ***CMAQ V5.0.2 NAM-X***: improvement in ozone over-prediction over the East
- ***CMAQ V5.0.2 NAM-X***: Strongest underestimate over West
- Meteorological impact nearly as large as CMAQ/Emissions upgrade

Day 2 8h O3 Daily Max

August 12, 2016



Operational

EMC Parallel w/ NOx Emissions reduced

CT & PA DEP Noted numerous mixed exceedences with V5.0.2 Near Real-time parallels

Experiments to address missed exceedences

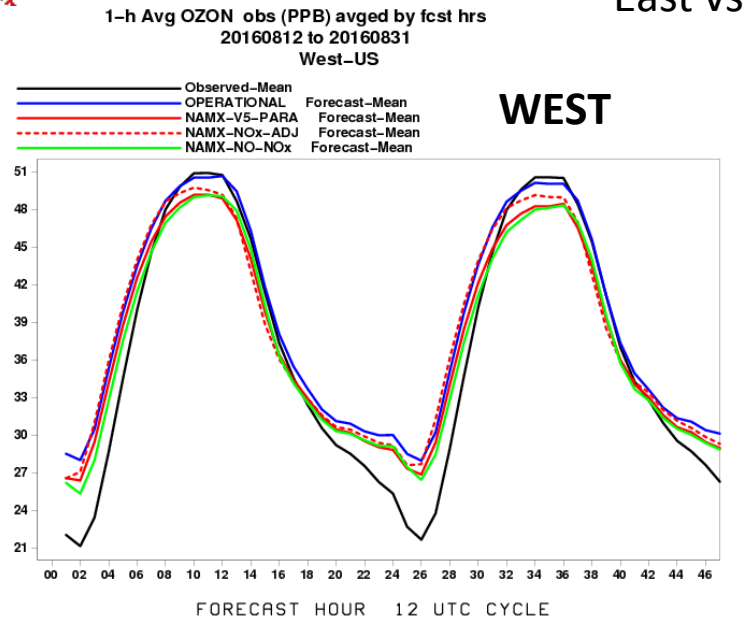
- No NOx Adjustment for Mobile Emissions (green line) NAMX
  - Cross State Air Pollution Rule (CSAPR) 2011 Mobile Emission
  - Should result in increased ozone production

- *Gridded NOx Mobile emission adjustment (red line) NAMX*
  - Adjustment factor also considers fine-scale features by taking into account the12 x 12 km grid-by-grid satellite-observed NOx to NAQFC forecasted NOx ratio

- V5.0.2 Para：State wide NOx adjustment using NAM

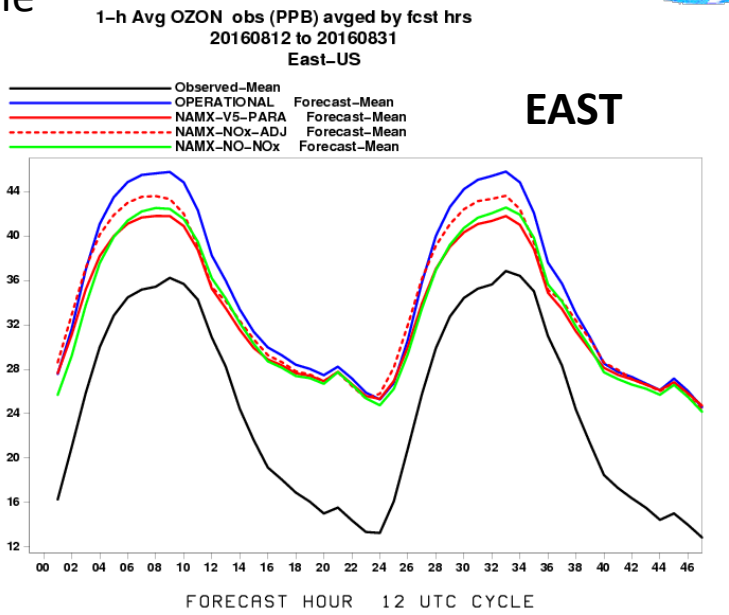
August 2016

East vs West Ozone



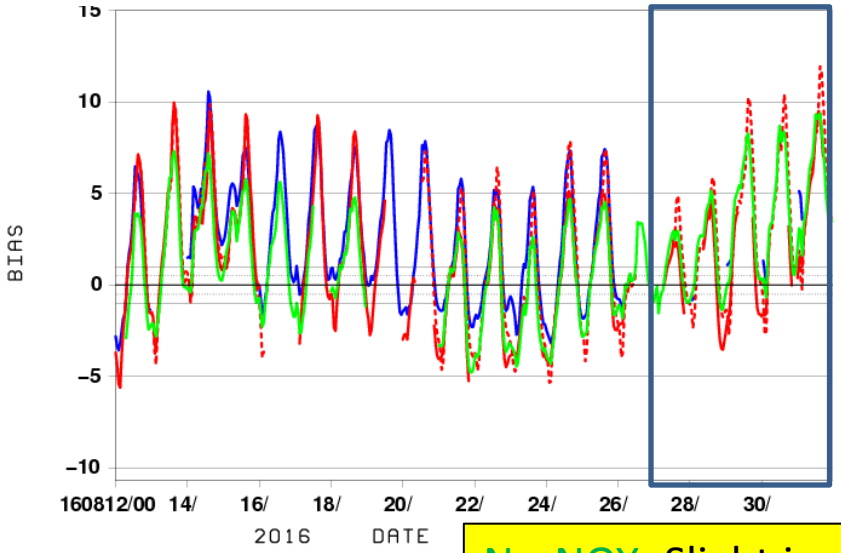
WEST

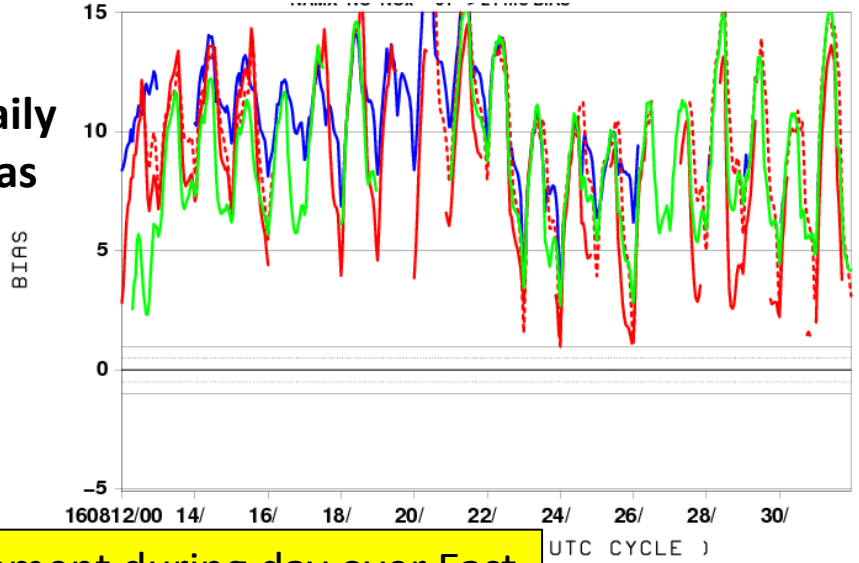
DIURNAL



EAST

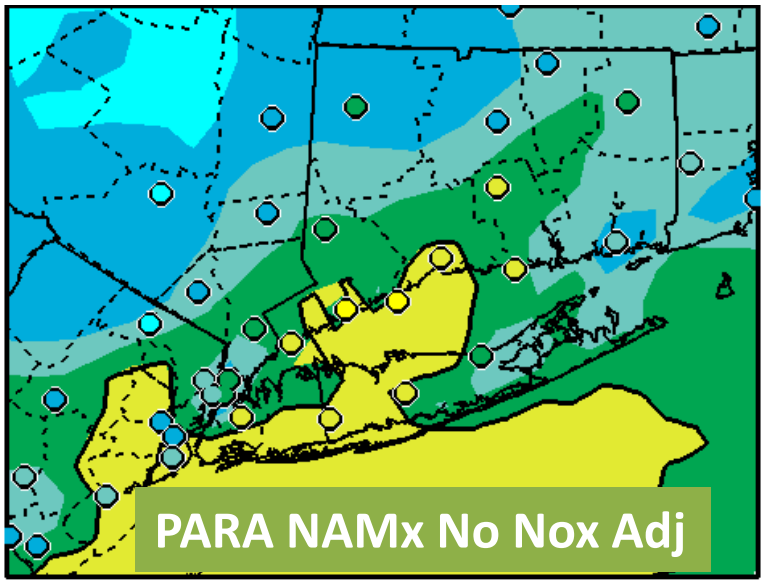
Daily Bias



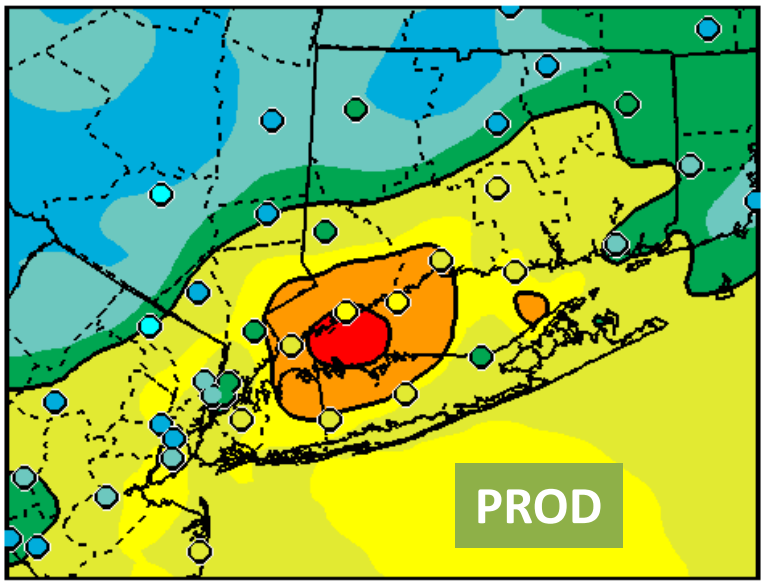


No-NOX: Slight improvement during day over East
Slightly better over West late August

August 18, 2016 Day 1



PARA 4X-DAY NAM-X NONOX DAY1 OZMX08 20160818 12Z CYC



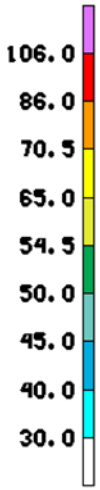
PROD AQM DAY1 OZMX08 20160818 12Z CYC

106.0
86.0
70.5
65.0
54.5
50.0
45.0
40.0
30.0

- NAM-X CMAQ V5.0.2:
  - **showed a great improvement over PROD**
  - Eliminated the four false alarms in PROD for August

Mike Geigart, CT DEP

May 17, 2017 8h Max Ozone



New York

Chesapeake Bay

Overestimate along N. Bay

- Bay Temps too warm

Parallel

PARA 4X-DAY DAY2 OZMX08 20170516 12Z CYC

PARA 4X-DAY DAY2 OZMX08 20170516 12Z CYC

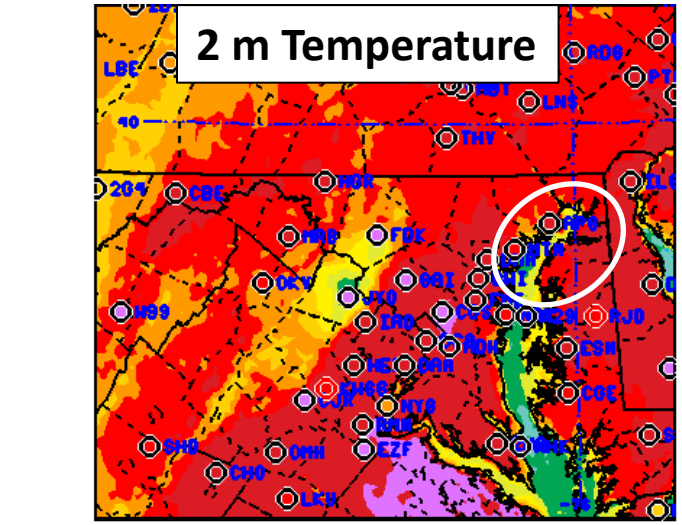
Production

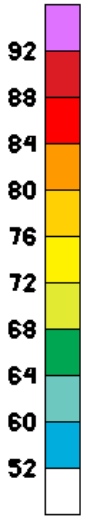
PROD DAY2 OZMX08 20170516 12Z CYC

PROD DAY2 OZMX08 20170516 12Z CYC

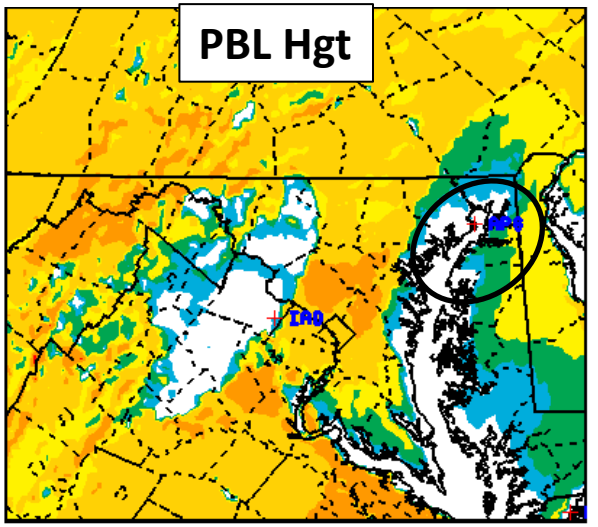
- More ozone formation in parallel run

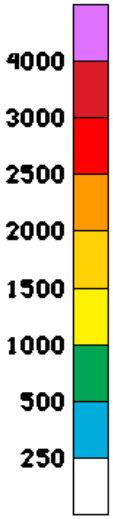
May 17, 2017 2 m Temperature/ZPBL

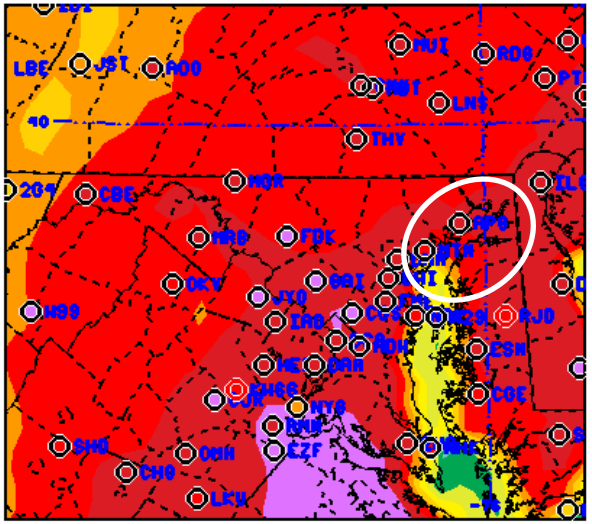




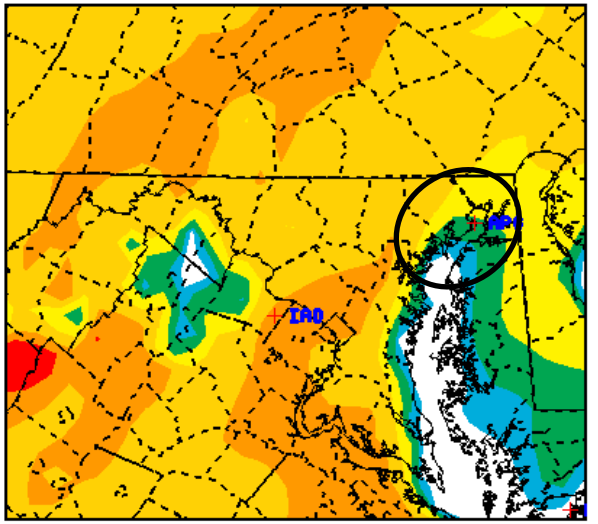
NAM-NEST-3 km







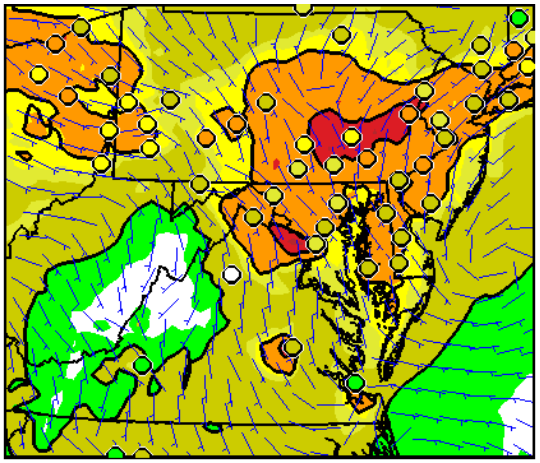
NAM-12 km

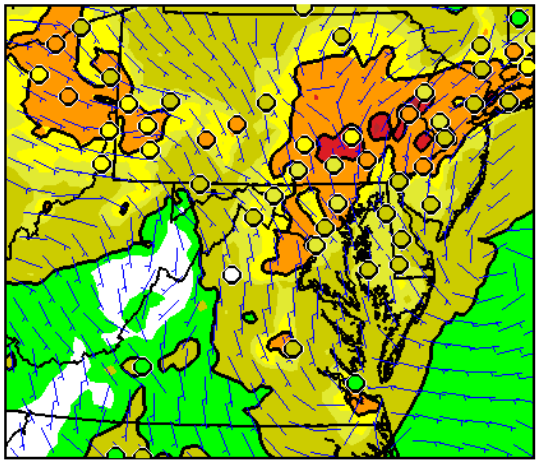


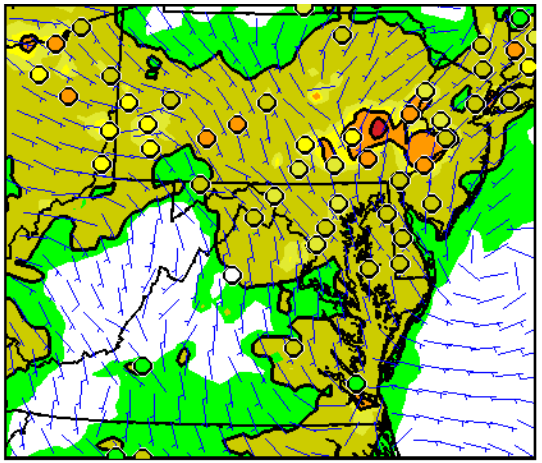
- N. Bay ~ 20° too warm in Parent
  - Treated as land

Wintertime PM

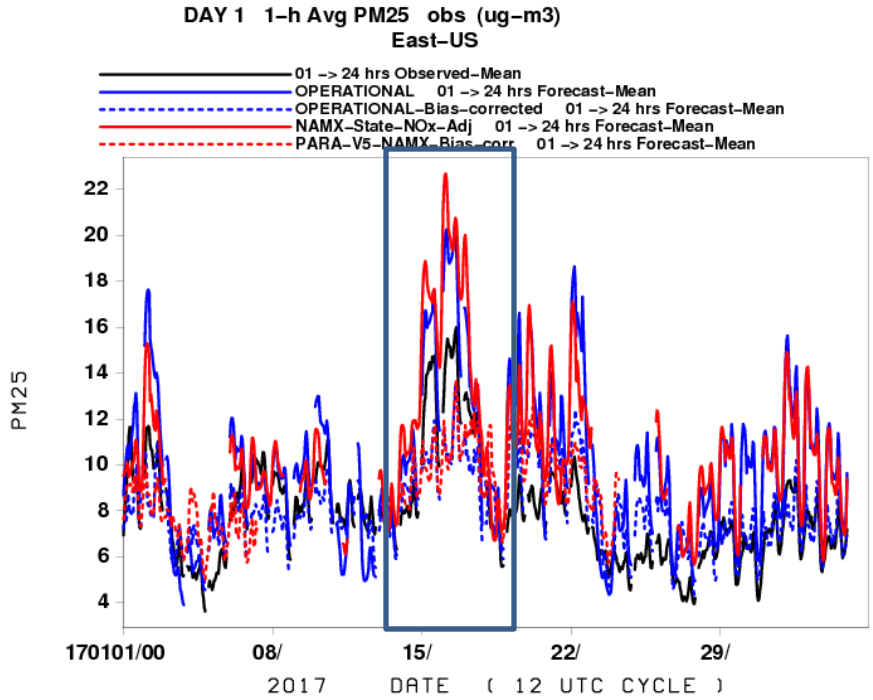
January 16, 2017 1hr PM2.5 Max





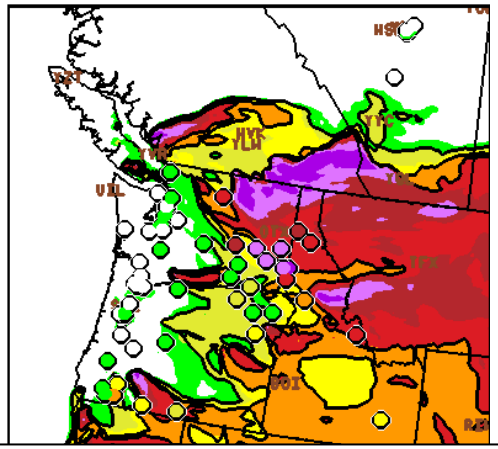


- V5: Small impact
- Bias Correction improves over-prediction

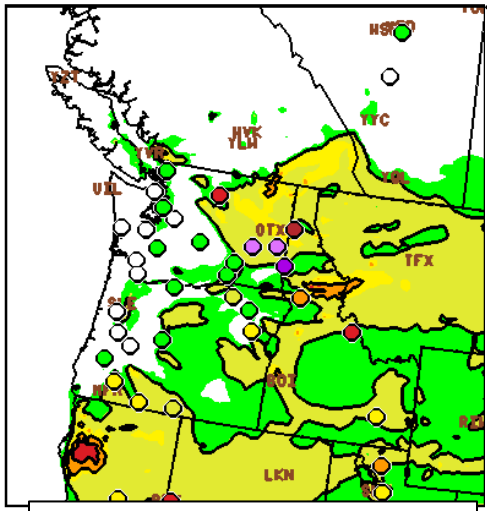


Western Fires

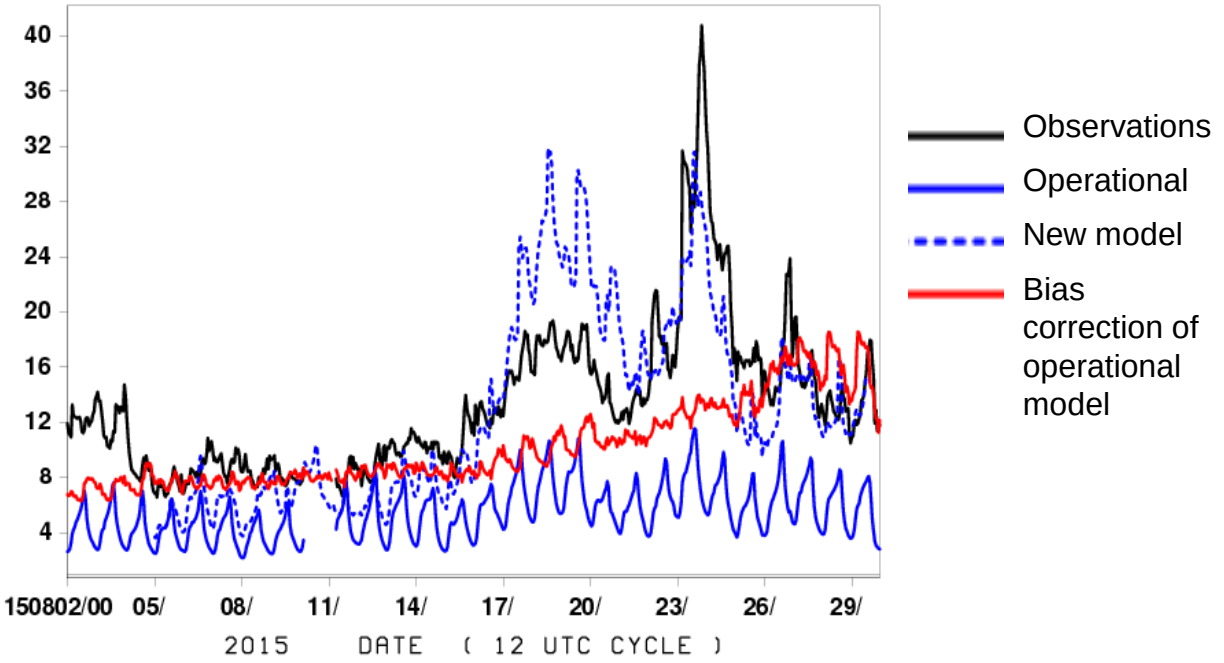
August 21, 2015 1hr PM2.5 Max



New Bluesky & 24 hr pre-analysis



Oper. Bluesky, no pre-anal



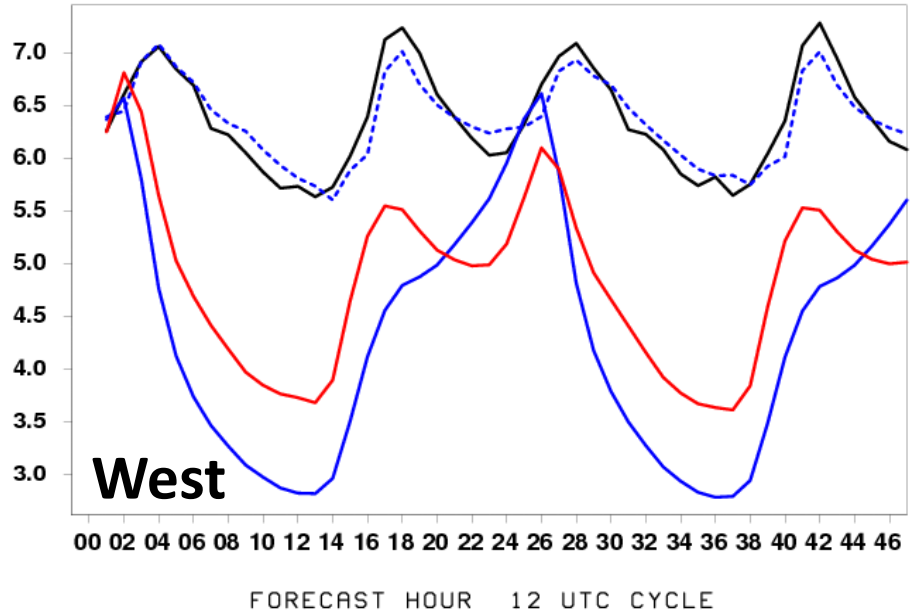
August 2015 hrly mean PM over West

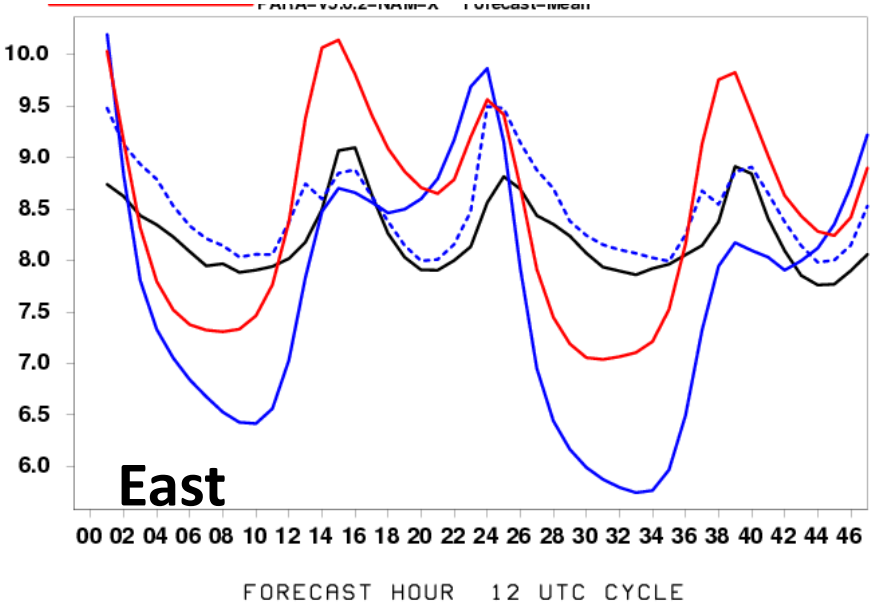
Operational runs: Most sites impacted by fire smoke are severely under-predicted.
Parallel model : Updated BlueSky and use of current day fire info

JULY 2016 PM Predictions vs obs

1 h avg PM

Observed–Mean
OPERATIONAL Forecast–Mean
CMAQ5XBC Forecast–Mean
PARA–V5.0.2–NAM–X Forecast–Mean

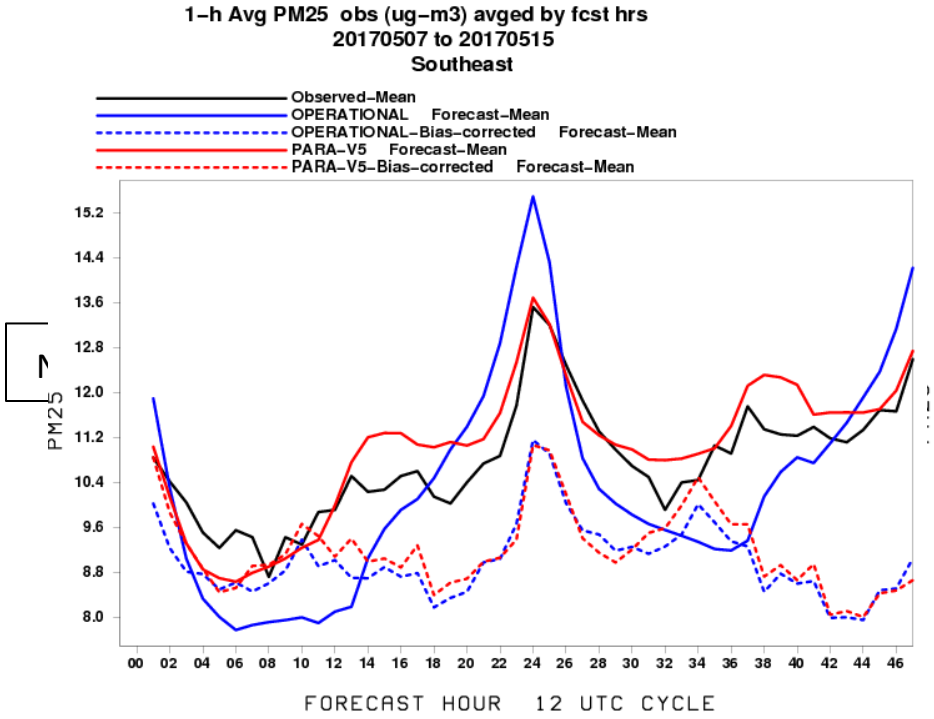


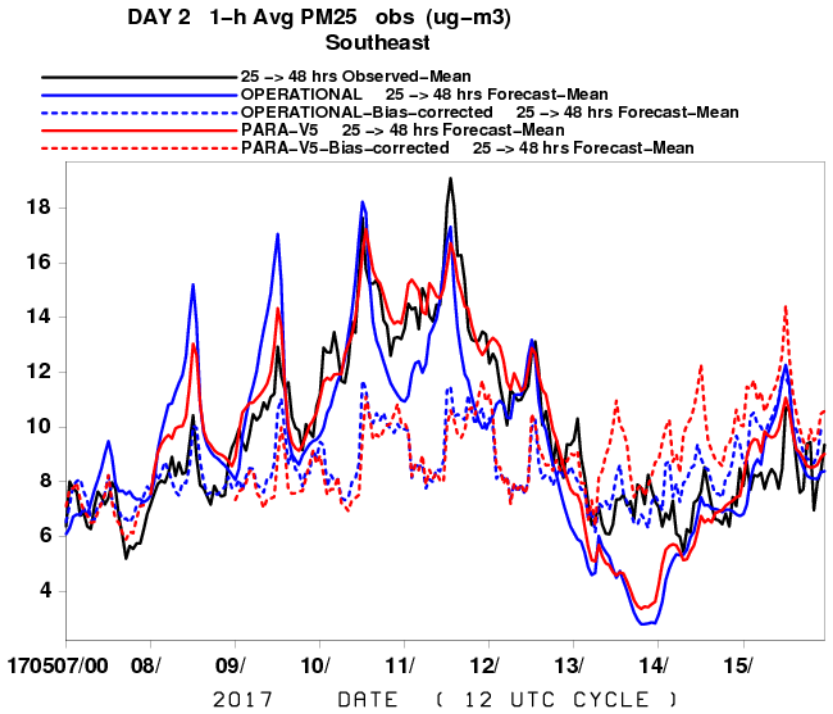


- Underpredict PM over Western U.S.
- Slight overprediction over Eastern U.S.
- *Bias Correction* strong improvement

May 7-15, 2017 Florida/Georgia Fires

1hr PM2.5

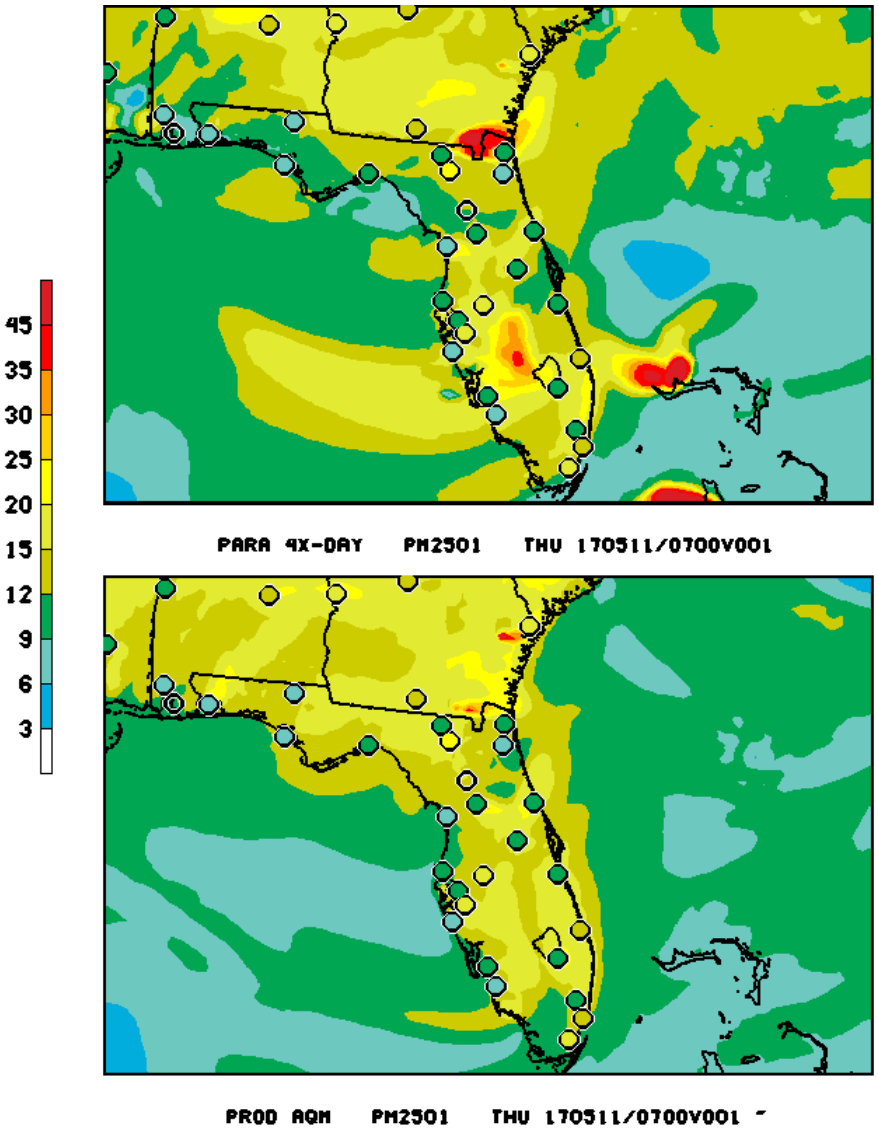


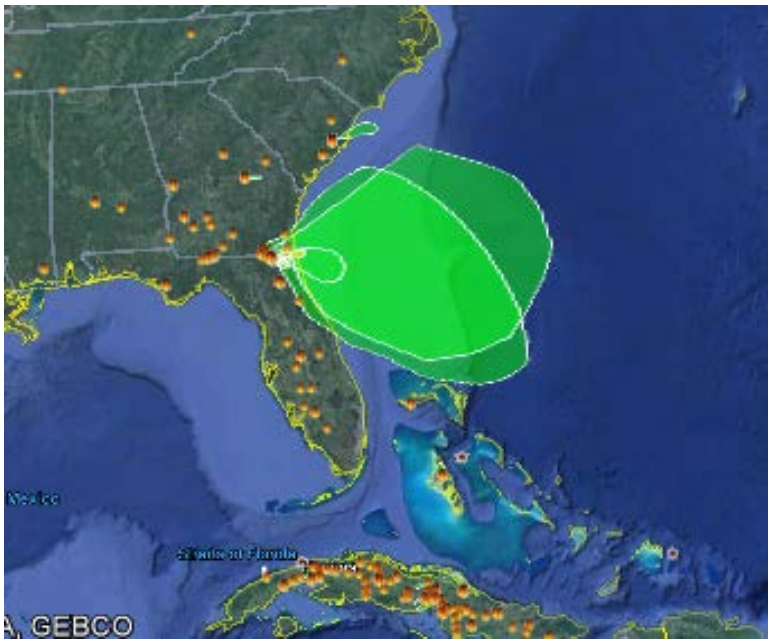


Raw-Parallel (solid red) follows diurnal pattern well
Bias correction underestimates fire event PM

May 11 2017 Florida/Georgia Fires

1hr PM2.5 loop





NESDIS HMS fire locations and smoke

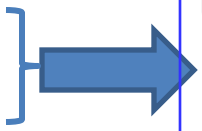
Para Captures FL and Bahama fires

Summary

- *V5.0.2 Ozone w/ NAM V4*
  - Improvement correcting over-prediction esp along coasts
    - Long Island Sound (CT DEP analysis)
      - » 7 False Alarms compared to 17 from production for NYC area
    - Lake Erie/Michigan and Ohio Coastline
  - Much improved for Southwest and marginal or non-events
  - Missed exceedences in NE corrected after removing NOx adjustments
- *PM*
  - Large positive impact near forest fires :
    - Updated BlueSky and 24 h pre analysis run
    - Underprediction when smoke external sources (Canadian fires) are impacting CONUS
    - Smoke emission timing and ejection height uncertainties
  - Continued overprediction in Winter from raw predictions
    - PM bias correction improves overprediction
- Updated NAM alone strongly improves ozone forecast
  - Amount of incoming radiation under clouds critical

Future Emphasis

- Extend to 72 hours, update emissions to 2017 base
- Near real-time fire locations, strength, emissions
  - Canadian, Mexican & external source impacts (from NGAC)
  - Improved temporal profiles and plume rise algorithms
  - Impact of wild-fire gas emissions on ozone
  - Top down (satellite) vs Bottom up (BlueSky) approaches
- NGAC full aerosol boundaries
- Unification of AQ systems
  - HYSPLIT smoke/dust → NGAC Aerosol
  - CMAQ ozone & total PM
  - HRRR-smoke



USWRP ESRL/EPA FV3-CMAQ
- Inline allows for High Resolution

- Extend Kalman Filter bias correction to *ozone*
- Improved Evaluations
  - Transition to MET+
  - Use of VIIRS/GOES-R/AERONET AOD, CALIPSO aerosols
  - Evaluate Operational models for field experiments (ESRL FireX 2019, FASMEE)

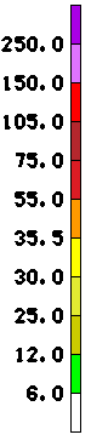
BACKUPS

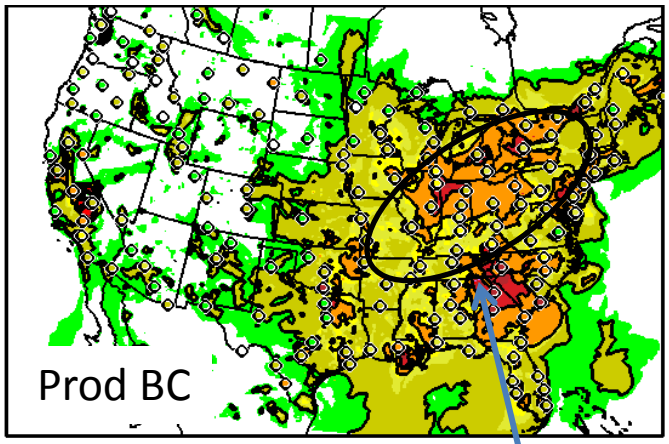
Web pages
CMAQ V5.0.2

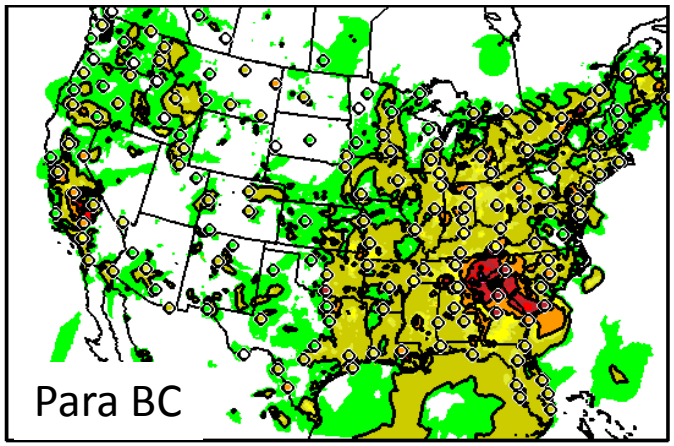
- Real-time parallel runs (July 2016-Present
  - http://www.emc.ncep.noaa.gov/mmb/aq/cmaq/web/html/max.html
- No NOx adj/NAM-X/4x-day cycling (Aug. 7-Sept 10)
  - http://www.emc.ncep.noaa.gov/mmb/aq/cmaqnox11/web/html/max.html
- Gridpoint NOx adj/NAM-X/1x-day cycling (Aug. 1-Sept 10)
  - http://www.emc.ncep.noaa.gov/mmb/aq/cmaqnox/web/html/max.html
- Verification statistics (prod,para, cmaqnox11, cmaqnox)
  - http://www.emc.ncep.noaa.gov/mmb/aq/fvs/web/html/regular.html

November 15, 2016

South East U.S. Fires: Midwest impact

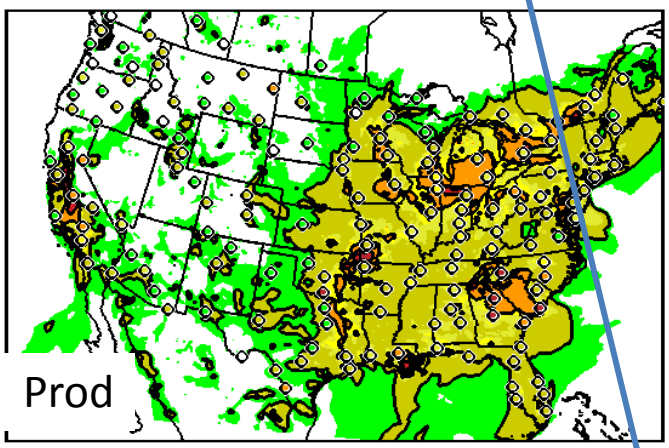


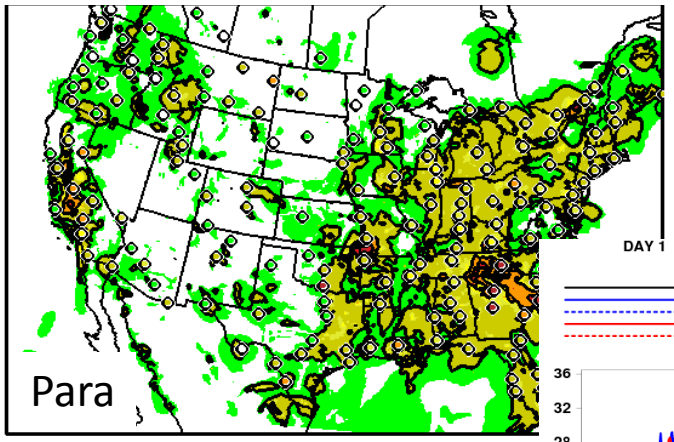




PARA 4X-DAY DAY1 PMMX01 20161115 12Z CYC

PARA BIAS BIAS COR DAY1 PMMX01 20161115 12Z CYC

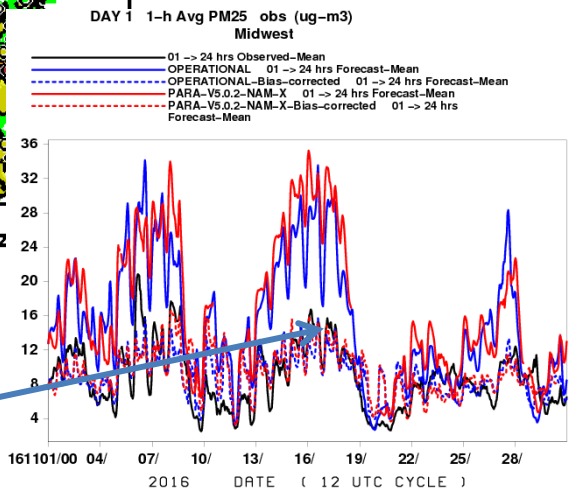




PROD AQM DAY1 PMMX01 20161115 12Z CYC

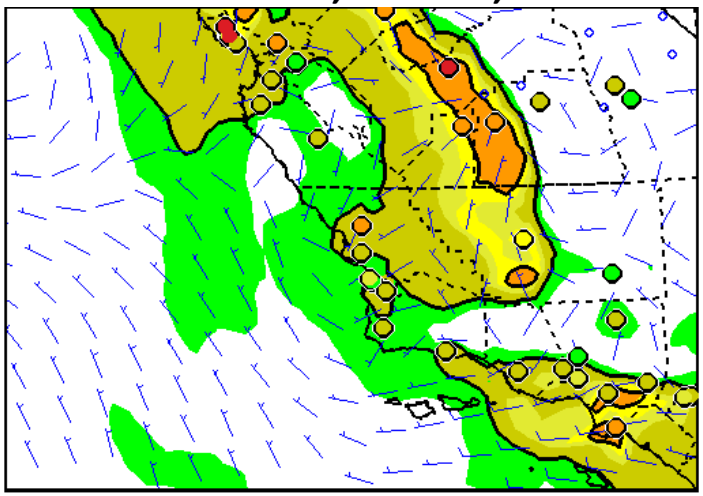
PROD BIAS COR DAY1 PMMX01 20161115 12Z

- Is smoke from fires moving too far downwind (Midwest)
- BC does good job for correcting in prod & para runs

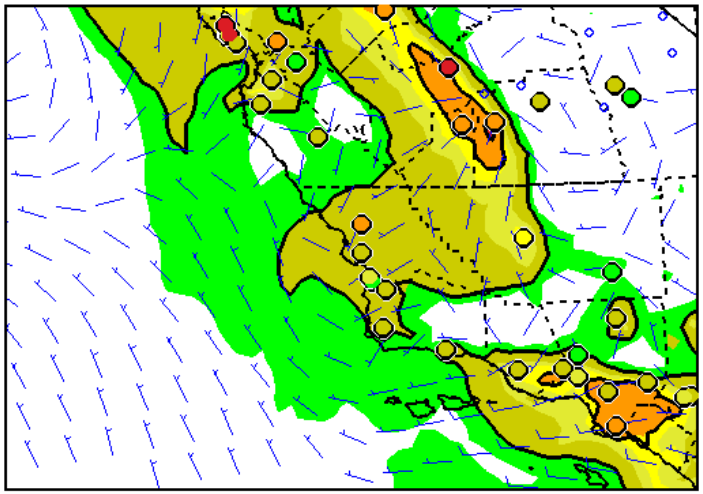


Winter Time PM

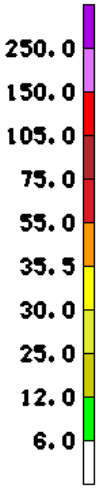
Southern CA, Jan. 17, 2017



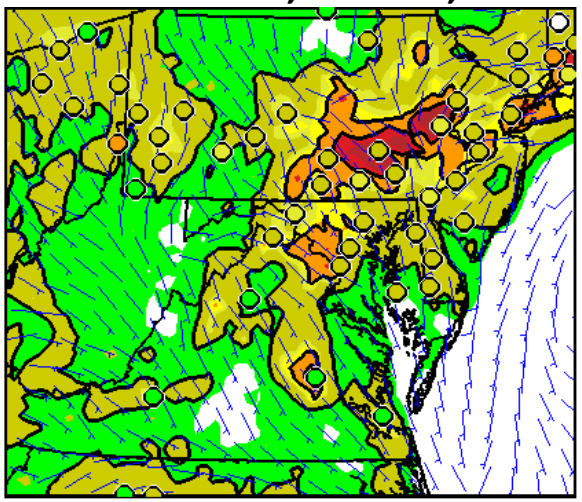
PARA 4X-DAY NAM-X DAY1 PMMX01 20170117 12Z CYC



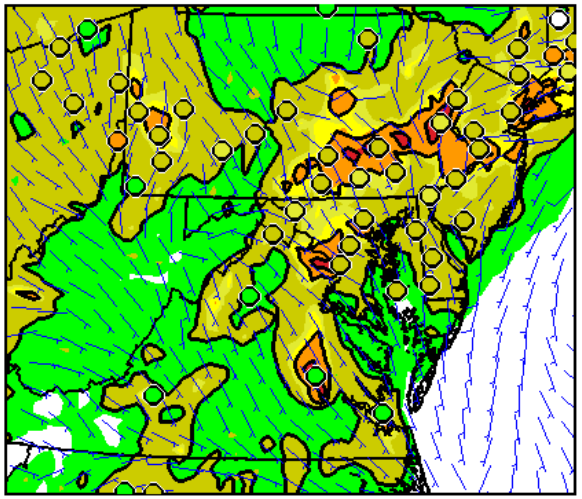
PROD DAY1 PMMX01 20170117 12Z CYC



Mid Atlantic, Jan. 21,2017



PARA 4X-DAY NAM-X DAY1 PMMX01 20170121 12Z CYC



PROD DAY1 PMMX01 20170121 12Z CYC

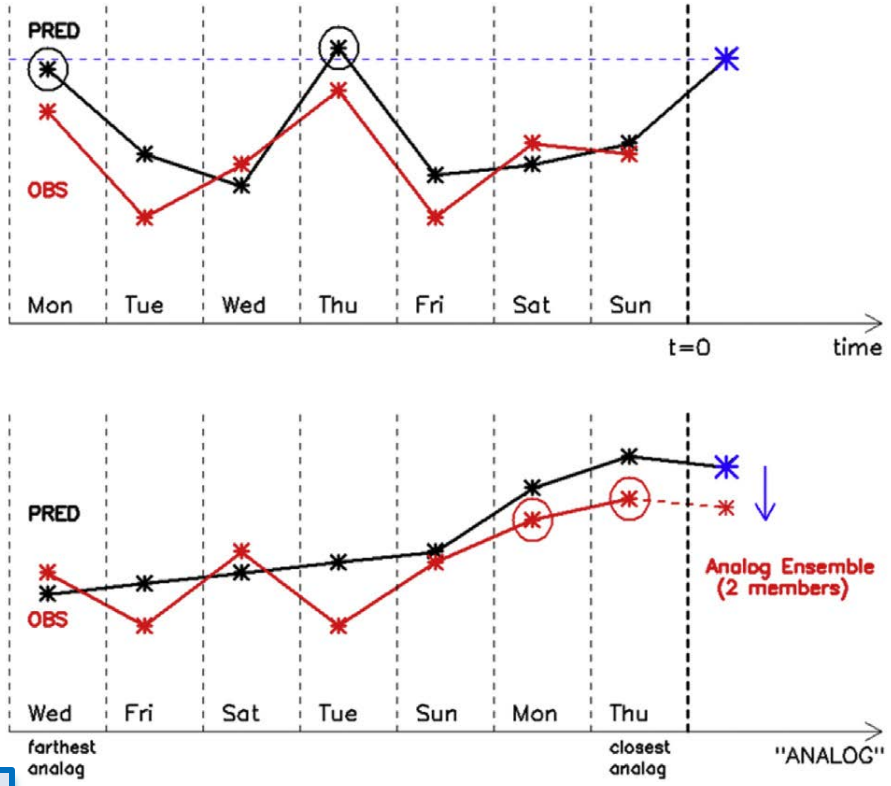
- Improved out west, but overprediction sometimes worsened over East

Analog Ensemble for $PM_{2.5}$ Bias Correction

- **Analog metric is determined by (Monache et al. 2011)**

$$\|F_t, A_{t'}\| = \sum_{i=1}^{N_v} \frac{w_i}{\sigma_{f_i}} \sqrt{\sum_{j=-\tilde{t}}^{\tilde{t}} (F_{i,t+j} - A_{i,t'+j})^2},$$

where F_t is current NWP forecast valid at future time t, $A_{t'}$ is analog at past time t', N_v is the number of variables , $\tilde{t}$ is half the number of additional computation time, w_i weight, σ_{f_i} standard deviation



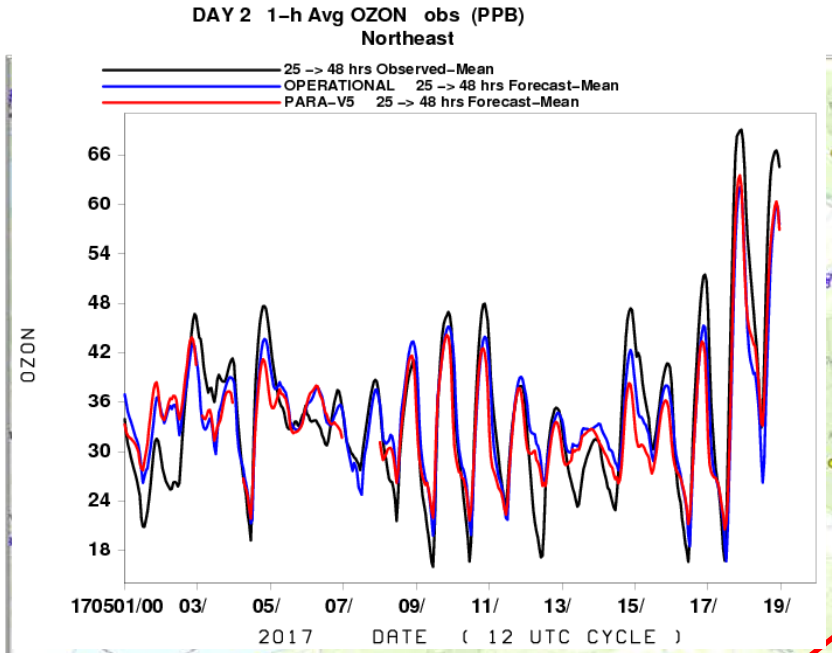
(Source: Djalalova et al., 2015)

Implementation in NAQFC

- **Variables for Analog search**: **$PM_{2.5}$, T_2, WS/WD**
- **Ensemble members: 5**
- **Training period: one year**

Courtesy Jianping Huang, EMC

May 18, 2017 8h Max Ozone



Courtesy Mike Geigart, CT DEP

- I95 Event VA to Maine/Nova Scotia *Exceedences*